



COASTAL HERITAGE

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1980-2020

S.C. Sea Grant Consortium

Marks Four Decades of Change

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Charleston artist Mary Edna Fraser turns aerial photographs taken from her family's vintage plane into batik-on-silk images that communicate messages of conservation and stewardship. The cover of this special issue of Coastal Heritage is one of her batiks that highlights the tidal waterways of South Carolina's Edisto Beach.

BATIK ARTWORK, EDISTO IV/MARY EDNA FRASER/REPRODUCED WITH PERMISSION

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Letter from Rick DeVoe, *Executive Director of S.C. Sea Grant Consortium*



M. Richard (Rick) DeVoe, executive director of S.C. Sea Grant Consortium.
PHOTO/WADE SPEES

Coastal Heritage's purpose through the years has been to provide a glimpse of life along the coast of South Carolina and the region, with a focus on the people, places, and programs which have shaped its coastal history, heritage, environment, and economy. And it provides perspectives and points-of-view meant to elicit thought and response. With the S.C. Sea Grant Consortium marking its 40th anniversary in 2020, this special issue of *Coastal Heritage* reflects on the last 40 years by offering snapshots of initiatives and activities, collaborations and partnerships, and science-based data and information which explore and examine the nature and value of how our coastal and ocean resources have supported and shaped us. What

we do know is that much change has occurred over the past 40 years, mostly for the better, as the state's coastal region and its assets have been discovered by many folks "from off." We are indeed blessed with a place which provides us the sustenance to succeed and prosper, but we are realizing this comes with the ongoing challenge that our resources are indeed limited.

However, as we remember and celebrate the work of the Consortium and the many hundreds of people who have been instrumental in making it happen, this 40th year has unexpectedly brought us an existential crisis (remember flooding?) which none of us have ever experienced before. As we look to the future, how will its presence shape our next year, 10 years, 40 years? How will it affect our governments and institutions, our universities and schools, our businesses and industries, our sustainability and resiliency, and our behavior; in essence, our "normal?" What will be the important "new normal" questions, challenges, and opportunities in the marine and coastal universe which will require our attention? The time is now for us to begin to assess – and reassess – how we, as purveyors of science-based information and assistance, explore the nature of the questions to come, and the means by which we may have to do business in the future, founded in our experiences and knowledge and guided by our foresight and vision for how the next 40 years will unfold.

I wish to also note that 2020 is not only a significant milestone for the agency, but it is for me as well. I began my professional career with the then-nascent S.C. Sea Grant Consortium

back in October 1980, fresh out of graduate school. Our office was located in the Medical University of South Carolina's "white house" out on the point at Fort Johnson on James Island. My University of Rhode Island contemporary, Margaret A. Davidson (who would direct the agency from 1983-1997: see tribute on page 31), and I came down to Charleston from Narragansett Bay – one week apart – to take on jobs with the Consortium. And, my goodness, things have changed so much along the way. I feel some of that change was the result of the good, and many times foundational, work the Consortium – its faculty, students, and staff – took on in order to make a difference and inform that change for the betterment of the state, its residents, and its coastal and marine resources. We have had a good 40 years.

Yes, indeed, these are challenging times. But every challenge brings with it opportunity, and I trust that we will see those opportunities as the means by which we survive, grow, and prosper. I trust we will.

Thank you all for your generous support, outstanding contributions, and unselfish efforts over the past 40 years to help make the Consortium what it is today. Now the real work must begin. ♡

1980-2020:

S.C. Sea Grant Consortium Marks Four Decades of Change

by Joey Holleman

For 40 years, the S.C. Sea Grant Consortium's researchers, educators, and outreach staff have worked to enhance understanding of the unique heritage and natural resources of coastal South Carolina. This special issue of Coastal Heritage details how the Consortium has examined the past, determined how particular factors are shaping the present, and how those factors could potentially drive the coastal region's future.

Forty years ago, the S.C. Sea Grant Consortium (Consortium) began with a mission of enhancing understanding of the unique heritage and natural resources of coastal South Carolina. The Consortium's researchers in various sectors set out to examine the past, determine how particular factors are shaping the present, and how those factors could potentially drive the coastal region's future.

The four-decade journey in some cases followed a linear path. For instance, the focus of aquaculture research moved from Malaysian prawns to local shrimp and then to clams and oysters, in search of the best fit for the state's ecosystem and economy. In most cases, new work built on the foundation of previous efforts, exemplified by a series of multi-year studies of water quality in tidal creeks and salt marshes. And some things never seem to change, with the impact of coastal population growth as much a concern in 2020 as it was in 1980.

Much of the work done by the Consortium in the past 40 years has been associated with maintaining and enhancing what lured people here then and now, the marine and coastal environment. A statement from Margaret A. Davidson, then assistant director of the Consortium, in the agency's biannual report in 1981 rings

true today. "Conflicting pressures can only be expected to intensify as the state's sea islands and alluring climate continue to attract both settlers and visitors. ... Our concerted efforts will help ensure the health and vitality of South Carolina's coast and its diverse ecosystem, in order that we may all enjoy the benefits which accrue while sharing the responsibilities for careful management of our resources."

The Consortium seed was planted in 1966 when Congress passed the National Sea Grant College Program Act, encouraging states to initiate and support education, research, and outreach related to coastal, marine, and Great Lakes resources. It was patterned after the land grant college concept, which dates back to the passage of the Morrill Act in 1862. The land grant program provides federal support for a university-based system for development of agricultural and mechanical advancements, with most of the funding coming from the U.S. Department of Agriculture. With the

new Sea Grant program's coastal and ocean focus, the federal home would eventually be in the U.S. Department of Commerce within the National Oceanic and Atmospheric Administration (NOAA).

The national program first took root in South Carolina in 1972, with Sea Grant operating within the S.C. Wildlife and Marine Resources Department (SCWMRD), now known



STAGE SETTER. Margaret A. Davidson, seen here checking out a clam mariculture operation with aquaculturist Colden "Colie" Battley, was assistant director of the S.C. Sea Grant Consortium at its formation in 1980 and set the tone for its operation as executive director from 1983-1997.

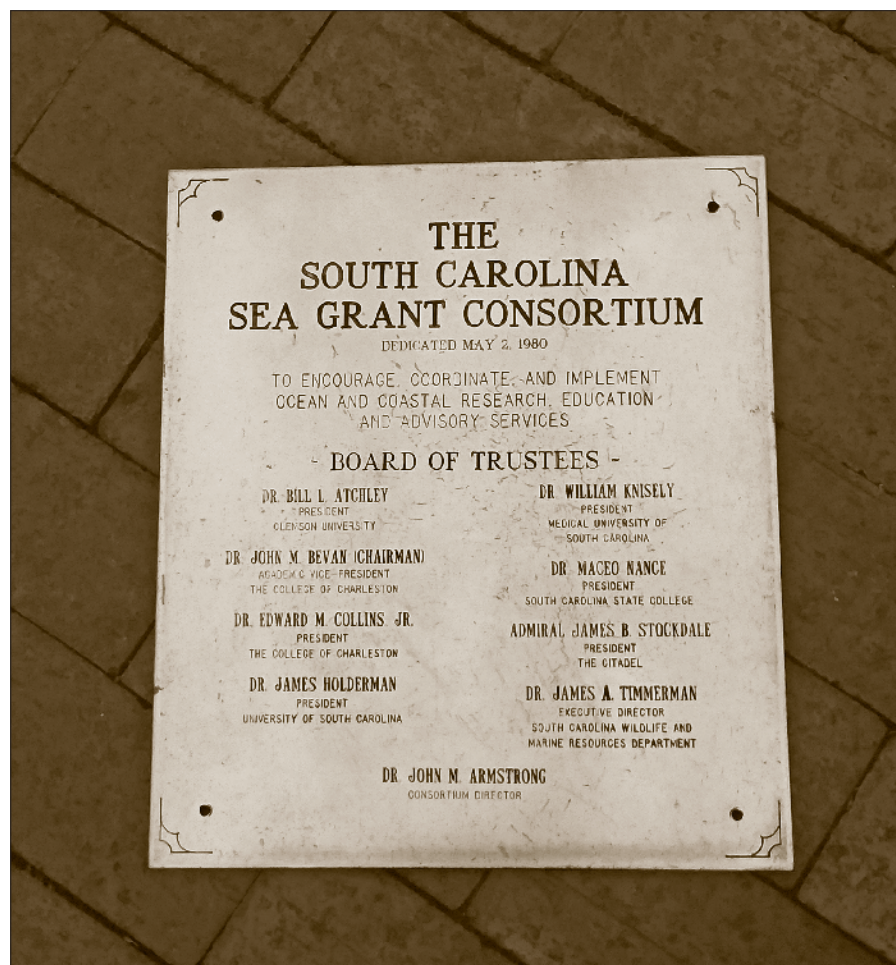
PHOTO/S.C. SEA GRANT CONSORTIUM

as the S.C. Department of Natural Resources (SCDNR). Governor John West in late 1971 had designated SCWMRD as the lead agency in what would be a program that involved state research universities. West appointed Edwin B. Joseph, then director of the SCWMRD Marine Research Laboratory, to coordinate an effort aimed at “promoting the legitimate interest of all educational and other appropriate institutions and agencies for the State in developing a significant Sea Grant Program for South Carolina.”

In 1978, state legislation created the S.C. Sea Grant Consortium as an independent state agency that included member institutions: Clemson University, College of Charleston, Medical University of South Carolina, South Carolina State College, The Citadel, University of South Carolina, and SCWMRD. Coastal Carolina University subsequently joined the Consortium in 1996. State funding for the agency was approved in the next budget cycle for the 1980 fiscal year, and the agency began formal operations that year.

By coincidence, 1980 was dubbed “The Year of the Coast” by President Jimmy Carter. The official declaration also could have described the need for, and design of, the Consortium. “The importance of the Nation’s coastal zone cannot be overstated,” Carter said. Noting the wealth of natural resources, economic activity, and recreational opportunities in coastal regions where population was booming, he said “this convergence of resources, activities, and people requires a close cooperation among all levels of government and a partnership between government and the private sector.”

Scientific research, education, and outreach are the Consortium’s primary means of examining and sharing what has and is happening in the coastal region by documenting the past, understanding the present, and helping prepare for the future. Competitive federal funding for the



STARTING POINT. A plaque marking the formation of the S.C. Sea Grant Consortium was dedicated May 2, 1980, and originally installed at the agency’s first office on Fort Johnson in James Island, S.C.

PHOTO/JOEY HOLLEMAN/S.C. SEA GRANT CONSORTIUM

Consortium’s work flows through the National Sea Grant College Program to the Consortium, which is augmented with 50% in non-federal funds. Sea Grant ensures that both the interests of the federal government and the state and its constituencies are understood and met.

When the Consortium began, no one could have predicted how the coastal region would change over the next 40 years. Coastal water quality research has gone from ecologically characterizing wetland impoundments in the 1980s to examining the effectiveness of stormwater ponds in the 2010s. The focus of coastal hazard studies went from mitigating beach erosion in 1980, to constructing buildings that better handle hurricane-force winds after Hurricane Hugo in

1989, and more recently to dealing with flooding due to expanding tides, rising sea levels, and a changing climate.

For the past four decades, the Consortium’s research, education, and outreach functions have helped coastal businesses, residents, neighborhoods, municipalities, planners, resource managers, and scientists anticipate, adapt, and react to those changes as well as plan for the future.

RESEARCH SUPPORTS AQUACULTURE OPERATIONS

From the beginning, one of the goals of the Consortium was to bring together teams of faculty and staff from the various member institutions to help solve problems. The first step in

that process often involves building a solid base of science through research.

The Consortium received funding for 30 research projects in its inaugural year, along with its supporting program management, extension, and communications programs. Research studies examined topics related to erosion control, beach access, urban waterfront planning, marine education curricula, economic value of the marine industry, effectiveness of car tires as artificial reefs, distribution and growth rates of flounder in the wild, and aquaculture practices for growing prawns, eels, and clams.

Paul Sandifer was the lead investigator on a Malaysian prawn study in 1980. Entrepreneurs in the fast-expanding aquaculture industry were searching for new products, and the large prawns would be an enticing addition if they could be adapted to grow in South Carolina.

"We exhausted every possibility known to mankind to see if we could grow those things in a more temperate environment," Sandifer says. "The reality is, yes you can. You can grow them all day long in warm weather, but they don't overwinter. When the economics are said and done, we could

never get the intensity of production up enough to make it commercially feasible."

Research, however, seldom is a complete bust. Sandifer has been pleasantly surprised to see some of the lessons learned in that study cited regularly over the years and even in recent research into growing the species in Thailand and elsewhere.

Since that early prawn work, the Consortium has backed research and provided information on many species for aquaculture, including crayfish, shrimp, catfish, clams, bait fish, and hybrid striped bass. For more than three decades, Jack Whetstone led the Consortium's aquaculture outreach effort. Much of his work involved helping new growers learn about the latest research, equipment innovations, and farming methods. The Consortium also produced several versions of a guide to South Carolina aquaculture permitting and regulations beginning in the early 1980s, which is currently being updated.

Throughout the past 40 years, aquaculture operations in the state have struggled to overcome economic and regulatory challenges, Whetstone says. Louisiana's wetlands are better

suited to growing crayfish. Catfish farming has been more successful in the mid-South region, especially in Mississippi. Foreign shrimp farms have lower regulatory and workforce costs. Concerns about disease and effluent from water-dependent operations present challenges, especially as farms grow in size. And the increasing demand for high-end homes on the water's edge makes development a more profitable option for that land than aquaculture operations.

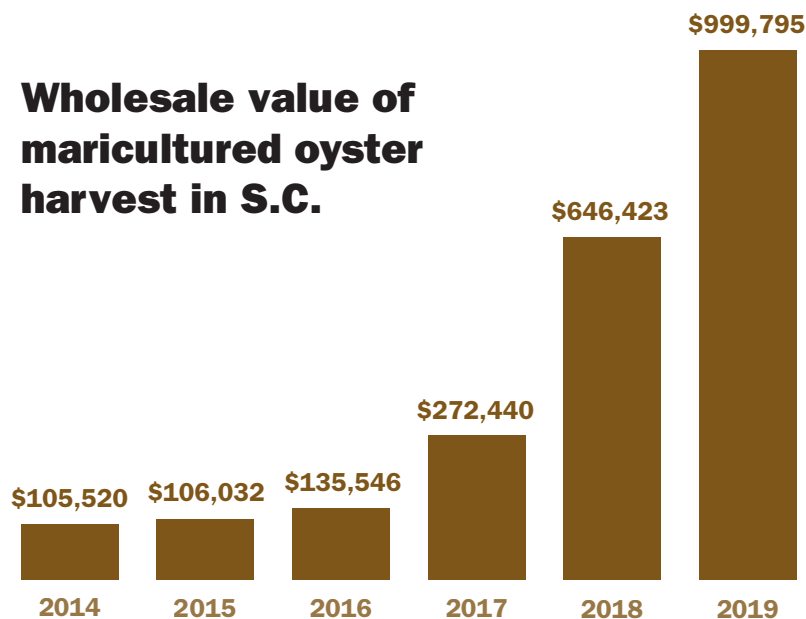
The Consortium assisted farmers in clearing hurdles where possible, with research into best growing practices, aid with marketing campaigns, and an effort that helped hard clam culturists in South Carolina qualify for federal crop insurance. And the major message to arise from the past four decades is that aquaculture operations work best in South Carolina as small businesses with limited administrative, distribution, and infrastructure costs.

"You can make money when you're small," Whetstone says. "But when you become large, you become a commodity and can't compete."

The state had 75 aquaculture farms in 2017, according to the U.S. Department of Agriculture. Among the largest sectors, 16 farms raised sport or game fish (such as smallmouth bass, largemouth bass, sunfish, crappie, bluegill), 16 raised crustaceans (crayfish, softshell crabs, shrimp), 15 raised mollusks (clams, mussels, oysters), and 10 raised catfish. Many of these farms were located inland and on private ponds, with catfish farms in Lexington, Orangeburg, and Pickens counties and crayfish farms in Anderson, Darlington, and Orangeburg counties.

Whetstone says the mollusk sector has the best potential for growth along the coast because farmers face fewer obstacles. Concerns about disease restrict foreign imports of oysters and clams, reducing competition in the market for local products. And regulations on effluent from oyster farms are less of a concern because

Wholesale value of maricultured oyster harvest in S.C.



SOURCE: S.C. DEPARTMENT OF NATURAL RESOURCES

GRAPH/CRYSTAL NARAYANA/S.C. SEA GRANT CONSORTIUM

oysters and clams are filter feeders that improve water quality as they grow.

Clam mariculture began to take off when the state legislature, in the late 1980s, revised laws to allow year-round harvest with no size limits for aquaculture farms. That prompted a flurry of research into best growing practices, much of it funded by the Consortium. Farmers experimented by stacking trays of clams in creekside tanks using upweller or downweller technology and with land-based raceways to push nutrient-rich water through the clams. Other farmers grew clams in metal trays, and later fabric bags, in tidal creeks.

And clam farming exploded, with harvest growing from less than \$6,000 in wholesale value in 1992 to \$90,732 in 1993, \$386,034 in 1994 and \$1,791,214 in 1995, according to SCDNR. The clam mariculture harvest peaked at just over \$2 million in value in 1999 before settling into an annual range of \$300,000-\$500,000 for the past two decades.

Over the last ten years, the Consortium has provided information, expertise, and training to support the recent emergence of oyster mariculture in the state. The oysters start out in hatcheries and then are transferred to floating mesh containers and placed in tidal waters, where they grow to market size. Julie Davis, the Consortium's former Living Marine Resources Specialist, helped farmers refine the process to grow oysters faster and less expensively. Locally grown single oysters have become popular in restaurants and raw bars.

The burgeoning industry almost collapsed in 2014, when concerns about the potential for disease transfer prompted state regulators to introduce a moratorium on seed oysters from the hatchery sources then common north of the state. The Consortium responded with equipment and training to help launch a hatchery at Lady's Island Oyster in Beaufort County. Instead of collapsing, the niche industry took off, with the value of maricultured oysters harvested



SWEET HAUL. Commercial fisheries for individual species in South Carolina waters have varied throughout the past 40 years, reacting to changes in economy and ecology, but blue crabs ranked as one of the top five landings in dollar value in 1980 and 2017. PHOTO/WADE SPEES

from state farms jumping from about \$29,000 in 2012 to over \$646,000 in 2018, surpassing clam harvest (\$459,108) for the first time.

"Thanks to technologies and techniques learned from Sea Grant, we are realizing that our long-term goals can be achieved," says Lady's Island Oyster owner Frank Roberts.

GENERATING SCIENCE TO GUIDE FISHERIES MANAGEMENT

In 1980, a significant focus of the Consortium's first round of research and outreach activity dealt directly with coastal fisheries. One of the first issues of the Consortium's *Coastal Heritage* publication explored the region's fishing culture dating back to

the mosquito fleet in the 1800s. These mostly African-American watermen headed to offshore banks in what amounted to dugout canoes rigged with small sails. Upon return, they hawked their fresh catch of blackfish, whiting, and porgy on the streets of Charleston.

Larger boats and more efficient harvest techniques prompted changes in the 1900s. In the 1930s, Florida shrimpers with European roots began to spend part of the year in South Carolina, introducing new trawling methods. Locals saw the large hauls and adopted similar methods, and soon shrimp grew from a niche harvest to a major fishery.

During the Consortium's 40 years, the business of fishing has performed



PARKING CHALLENGES. *As more people have moved to the South Carolina coast, more recreational boaters have flocked to the waterways, and that leads to traffic jams at boat landings.*

PHOTO/WADE SPEES

a not-always-delicate dance with the scientific management of fisheries. The background music is the Magnuson Fishery Conservation and Management Act of 1976, which created eight regional councils to develop management plans for federal waters. In this region, the South Atlantic Fishery Management Council sets the guidelines. Federal legislation later was tweaked by the Sustainable Fisheries Act of 1996, which put more emphasis on preventing overfishing, minimizing bycatch, and protecting habitat.

John Mark Dean, distinguished professor emeritus at the University of South Carolina (USC), says it is important to understand the difference between overfished and overfishing. “Overfished is what you have done,” he says. “Overfishing is what you are doing. When you take steps to reduce overfishing, then the overfished part of your fishery recovers.”

Fishery scientists analyze

abundance and composition of fish stocks, information used to regulate the opening and closing of seasons and harvest levels of a variety of targeted species, some of which are overfished. At the end of 2018, NOAA listed 43 species on the overfished list and 28 on the overfishing list, out of 470 stocks monitored. In the Southeast, the hogfish, red snapper, red porgy, and snowy and red grouper made the overfished list, which prompted management responses.

Management decisions can be challenging to commercial and recreational fishers. Some have raised concerns through the years about regulations that limit their catch of king mackerel, red snapper, red drum, and several species of grouper. However, Dean thinks the system is working well to maintain those species for future fishers.

Sometimes species need a boost from scientific advances. For instance,

the Consortium helped fund studies on raising red drum. Soon, however, fishery assessment studies began to show a decline in regional stocks of red drum in the wild, and this led to multiple investigations into stocking hatchery-reared red drum in the wild, says David Whitaker, who worked on the project while at SCDNR.

The first step was to examine the genetics of the species and develop stocking standards that would maintain genetic diversity. This was followed by SCDNR geneticists developing techniques to quickly examine the genetics of wild-caught fish by testing a tiny piece of a fish’s fin to determine if it was a stocked fish. The previous method used external tags. This technique has since expanded to identify other stocked fish species such as cobia and spotted sea trout.

“Responsible stock enhancement efforts provide this tool for fishery managers to use in addition to restrictive management actions,” Whitaker says. “Sea Grant’s funding played a role in providing several patches in the quilt that now provides a very good tool to deal with enhancement of fish stocks and to better understand the health of wild populations.”

Through the past four decades, there have been few new entries in the list of major commercial fisheries in the state. In 1980, the top five commercial landings by dollar were white shrimp (\$8.4 million), brown shrimp (\$4.6 million), blue crabs (\$1.6 million), oysters (\$1.2 million), and swordfish (\$1.2 million). The top five in 2017 were white shrimp (\$7.4 million), blue crabs (\$5.5 million), oysters (\$2.6 million), swordfish (\$1.8 million), and snapper (\$1.1 million). Snapper and brown shrimp were in the top 10 in the years they didn’t make the top five.

But overall, the state’s commercial fishery has slipped in the past four decades. According to the S.C. Seafood Alliance, seafood production averaged nearly \$40 million per year from 1950-1995, peaking near \$75

million in the late 1970s. A rapid decrease began in 1995, and the annual seafood production averaged around \$24 million from 2007-2016. (All of these figures are in 2016 dollars.)

Factoring in inflation, the dollar value of the top fisheries in 2017 was less than in 1980, an indication of the reduction in the fleet as fishing has become a less lucrative business. Dean believes commercial fishing has a future in the state, as long as fuel and ice availability and freezing or processing services can be maintained at several working waterfront locations. He wonders, however, if commercial fishing in the state should follow the blueprint of small farmers on land, which involves the direct

marketing of niche products to bring higher prices. If Carolina Gold Rice and Geechee Boy Mill Blue Grits can sell for premiums, so can Bulls Bay shrimp or Port Royal Sound oysters.

Even as fewer commercial fishing boats trawl in state waters, the number of recreational fishing licenses sold in the state has increased steadily for the past four decades. An average of 416,132 fishing licenses were sold annually during the 1980s, compared to 557,919 annually in the 2010s, an increase of 34.1%. And those license-holders are getting out on the water in record numbers. From 1981-2017, the number of angler trips on private, rental, or charter boats from South Carolina increased 243%, according to NOAA's Marine Recreation

Information Program.

In 1980, one of the Consortium's first economic studies looked at the impact of rising fuel costs on recreational fishing. Since then, fuel prices have been generally going up for four decades, but they have had little effect on the number of recreational fishing trips. The concern has changed from getting more recreational boats on the water to regulating their catch of overfished species.

MAINTAINING WORKING WATERFRONTS CRITICAL FOR COMMUNITIES

Working waterfronts, those small traditional municipalities dotting the South Carolina coast, provide



SORTING PRIORITIES. *The draw of tidal creeks as locations for homes and restaurants in the past 40 years has put pressure on their former use for commercial fishing, seafood processing, and ship building, but communities have worked to support traditional waterfront industries such as shrimping.*

PHOTO/GRACE BEAHM ALFORD

waterway access to dock space, fuel, and freezing or processing for commercial and recreational fishing; convenient locations for shipping, ship building, and maritime equipment repairs; water recreation; local restaurants and shops; and other activities. Efforts to ensure a future for working waterfronts touch on development and growth, socio-economic and demographic changes, and healthy fisheries and fishing industries.

High-end housing and marinas have become more prevalent along former working waterfronts in South Carolina over the past 40 years. And as communities struggle with the challenge of maintaining working waterfronts, the commercial fishing sector also deals with a labor challenge. Fewer young people are willing to put in long hours on the water to haul in shrimp or finfish. Even those who make that commitment now struggle to earn a comfortable

living in an industry strapped by rising fuel and insurance costs, increasing competition from imports, and extreme variability in volume of catch from year to year.

Rutledge Leland has seen the industry shrink in five decades at the helm of Carolina Seafood in McClellanville. A little more than a decade after Leland took over as manager of the family company, Carolina Seafood handled shrimp and other seafood caught by nearly 60 boats in 1980. Back then, Leland and other major players in the seafood industry owned multiple boats and hired captains and crews for them.

In 2019, about 18-20 boats routinely offloaded shrimp and other catch at Carolina Seafood's dock. Leland no longer owns any commercial fishing boats, but he says the business of processing and selling the catch from the remaining boat owners to restaurants, retailers, and the general public remains viable. The problem is

Leland can't keep doing his job forever, and he says nobody in his family or the local fishing community wants to take over.

In 2015 and 2016, Consortium researchers and graduate students met with boat captains, local decision-makers, and community planners in McClellanville and four other small working waterfronts in the state – Georgetown, Murrells Inlet, Port Royal, and Mount Pleasant's Shem Creek – to discuss these issues. Those trips revealed five unique communities facing their own challenges, including fishing-dedicated dock space, ice availability, lack of nearby processing facilities, and real estate pressures.

The research group put together community meetings to discuss the findings. Those who attended the meetings agreed with the report's consensus that each community recognized the value of maintaining a working waterfront; that potential conflicts over land use needed to be

addressed; and that each community must determine its ideal balance of commercial and recreational fishing and tourism.

Most of the communities took in the findings of the study and worked on changes internally. McClellanville reached out for help, applying for and receiving a grant from the Municipal Association of South Carolina (MASC) to explore how best to ensure the future of the Carolina Seafood enterprise. To avoid the sale of the working dock for its real estate value, McClellanville town officials and the East Cooper Land Trust looked into the prospects for a conservation



POPULARITY CRISIS. Mount Pleasant's Shem Creek featured a couple of restaurants, a seafood retailer, and a dozen or more commercial fishing boats in 1980. By 2016, the creek attracted more restaurants and many recreational users, but had fewer commercial fishing boats.

PHOTO/GRACE BEAHM ALFORD

easement with Leland. He says he is open to the idea, eager to protect traditional waterfront uses and the fishing heritage/culture that has been a large part of the community's identity for the past century.

"I want to keep these guys with a place to work," says Leland, who also serves as McClellanville's mayor. "I don't want it to become a condo city. I want it to be a commercial fishing dock. I'm part of the community, and that's what I'd like to see."

The Consortium and East Cooper Land Trust are partnering on the MASC grant project. To keep the business viable, they examined successful commercial seafood cooperatives in other states.

The application for the grant offers a blunt warning that the town is at risk of losing an entire way of life and heritage of maritime work. "Without intervention to protect the use of the docks, it is likely that the land will be sold and converted to other uses, ultimately ending the local seafood trade. This is not an unfounded fear, as there is precedence within the village itself. Less than 20 years ago, the town experienced this when a local crab company's waterfront property was sold, rezoned, and developed with million-dollar vacation homes."

POPULATION, HOUSING EXPAND, PROMPTING ECOLOGICAL BALANCE CONCERNS

Population growth and residential development rank among the most profound changes in the past four decades in coastal South Carolina. The state's population jumped from slightly more than 3 million in 1980 to 5 million by 2018 (about 66%), according to the U.S. Census Bureau. The eight coastal counties grew even faster – up 116% from 685,986 in 1980 to an estimated 1,478,755 by 2019.

A 2003 Clemson University urban growth study funded by the Consortium looked at the ratio of urban area growth to population



URBAN SPRAWL. *New subdivisions have been carved out of former woodlands for the past 40 years, as the coastal South Carolina population has more than doubled, affecting the ecology of the region.*

PHOTO/WADE SPEES

change in Berkeley, Charleston, and Dorchester counties from 1973 through 1994. The urbanized area in the three counties rose by 256% and the population grew by 41%, which means developmental sprawl was outpacing population growth by a 6:1 ratio. If growth continued at that rate, the region was going to run out of land to build on.

Jeff Allen, who worked on that study and now is director of the S.C. Water Resources Center at Clemson University, made presentations on the findings throughout the region. He would go to a high-end scenario and note "this is the worst case if we don't do anything, if no policies change and no ordinances are enacted to slow growth."

Counties and municipalities put together comprehensive plans, some of which include restrictive urban growth boundaries designed to balance the desire for economic growth with the goal to slow residential construction. But the rules still have favored economic growth, Allen says, and have done little to hold back the wave of new houses. The number of individual housing units in coastal counties

jumped from 249,170 in 1980 to 680,953 in 2017. The U.S. Census Bureau estimated in 2017 that 71.1% of all housing units in the coastal counties had been built since 1980.

The status-quo rate of growth in the 2003 study estimated Berkeley, Charleston, and Dorchester counties would reach a combined population of 800,000 by 2030. Growth has been closer to the study's worst-case scenario, with the tri-county population hitting an estimated 802,000 in 2019, according to the U.S. Census Bureau.

All of that growth right up to the edges of tidal wetlands and river flood plains squeezes these important ecosystems. But while the number of people and houses in coastal counties has expanded, so has the protection of critical areas. For example, conservation groups or land trusts bought Otter Island (1993), Pine Island (2003), and Morris Island (2008) and turned them over to government agencies. S.C. Parks, Recreation, and Tourism bought St. Phillips Island in 2018, with plans for minimal development as a passive park. Private owners donated much of Waties Island and Pritchards Island

to universities to serve as research preserves. And many private land-owners embraced the growing trend of putting large tracts under conservation easements, deed restrictions that limit future development on property even if it is sold.

Easements were particularly important in the area drained by the Ashepoo, Combahee, and Edisto rivers. In 1980, only geographers might have referred to that region as the ACE Basin. Now, it is world renowned as a major estuarine ecosystem largely protected from development, in part because of the 217,000 acres under private conservation easements.

In the eight coastal counties, about 1.2 million acres, or nearly 25% of the total land area, are protected from development. Of that protected land, 530,543 acres are privately protected, according to The Nature Conservancy.

Nearly 100,000 acres fall under the management of the ACE Basin National Estuarine Research Reserve (NERR), and farther north along the coast about 19,000 acres make up the North Inlet-Winyah Bay NERR. Both are important partnerships between NOAA, state agencies, and state universities and serve as living

laboratories for the effects of development near them.

By 2020, the expanding Charleston, Beaufort-Hilton Head, and Myrtle Beach-Georgetown urban corridors had begun to run into protected lands in the Santee River delta and the ACE Basin. In the coming decades, Allen says, developers are going to find it harder to locate rural land to develop and have to turn to infill, increasing the density in existing urban areas.

That, in turn, will necessitate more emphasis on sustainable smart growth and low-impact development practices the Consortium has been examining since 1980. Throughout that period, the Consortium has provided funding and assistance for projects to understand the underlying ecological and social values of coastal properties and to inform decision-makers as they sought to plan for growth.

The Consortium directed research in the 1980s into the ecological effects of former rice fields, many of which had been managed for decades to attract waterfowl for hunting. This work was critical because former rice impoundments constituted 15% of the state's 504,000 acres of tidal wetlands.

Two long-term projects examined the impacts of development on watershed ecosystems, and informed the production of *Low Impact Development in Coastal South Carolina: A Planning and Design Guide*. And for the past decade, funding research into how well stormwater ponds accompanying new development reduce flooding and improve water quality.

IMPOUNDMENTS: VESTIGES OF HERITAGE AND JEWELS OF COASTAL ECOSYSTEMS

In terms of re-engineering coastal waterways, rice impoundments predated stormwater ponds by a couple of centuries. The harvest of rice in the 1700s and 1800s not only enriched landowners, it transformed the ecology. At one time, impoundments accounted for 144,000 acres, or about 28% of the state's approximately 504,000 acres of tidal wetlands.

The rice economy collapsed in the late 1800s, when enslaved workers gained freedom after the Civil War and then were wiped out by a string of devastating hurricanes in the 1890s. But many of the impoundment dikes and wooden gates, called trunks, remained. Wealthy Northerners who purchased many of the former plantations as winter retreats found the engineering that facilitated rice production also could be used to create an ecosystem ideal for drawing birds, especially ducks. They created a new outdoor recreation economy along the coast.

In 1980, about 15% of coastal wetlands in the state remained impounded and managed for waterfowl. As landowners requested permits to repair dikes and trunks or reim-pound former rice fields, federal and state environmental regulators realized they knew little about these specialized ecosystems – how many were functional, how best to manage them, or how they affected marine life and estuarine function. The multi-year, Consortium-funded Coastal

Coastal population growth by county

	1980	2019	
Beaufort	65,364	192,122	+194%
Berkeley	94,727	227,907	+141%
Charleston	276,974	411,406	+49%
Colleton	31,776	37,677	+19%
Dorchester	58,761	162,809	+177%
Georgetown	42,461	62,680	+48%
Horry	101,419	354,081	+249%
Jasper	14,504	30,073	+107%
TOTAL	685,986	1,478,755	+116%

SOURCE: U.S. CENSUS BUREAU

GRAPHIC/CRYSTAL NARAYANA/S.C. SEA GRANT CONSORTIUM

Wetland Impoundment Project (CWIP) worked to come up with answers.

“Back then, the best ways to manage impoundments were passed along by word of mouth,” says Phil Wilkinson, who managed several impoundments during his long career with SCDNR. “Nothing was set in scientific literature.”

Wilkinson, who earned a master’s degree in wildlife management from Auburn University, had tried. His staff rebuilt rice fields on Cat Island at the Yawkey Wildlife Center near Georgetown into seven separate impoundments in the late 1960s, each with slightly different water salinity levels. He then experimented with different vegetation at different times of the year in each impoundment.

As that project progressed, it became clear what worked best in the medium salinity on Cat Island differed from what worked best in the high-salinity impoundments next door on South Island. And freshwater impoundments farther inland were a completely different ecosystem.

“You can’t apply one management routine across the coast,” Wilkinson says. “There’s so much variability in the habitat.”

To help individual impoundment managers, however, CWIP researchers aimed to determine overarching science. Using the same five impoundments on Cat Island, they looked at the hydrology, the flow of nutrients in and out, and the recruitment and growth rates of important species. Researchers also chronicled the ownership, structural status, and management techniques for impoundments throughout the coast.

They found 80% of the impoundments were used for hunting, fishing, or shellfish harvesting. The dike-and-trunk systems in a vast majority (83%) were either in working order or so deteriorated that the wetlands were considered “formerly impounded.” Only about 17% were candidates for repair, and because of the expense, the report surmised



UNIQUE WETLANDS. *Wooden trunk structures, many of them remnants of former rice plantations, control the flow of water in coastal impoundments in South Carolina, and Consortium researchers studied those ecosystems to help owners manage them.*
PHOTO/DAN TUFFORD/UNIVERSITY OF SOUTH CAROLINA

regulators would get few new requests to fix former dikes or trunks.

The researchers observed that concentrations of dissolved oxygen grew especially in July and August. They detailed more plant diversity and less fish diversity in impoundments than in adjacent tidal wetlands. And they documented that impoundments were important habitat for waterfowl, shorebirds, and endangered alligators.

Researchers recommended managing trunks to allow at least 10% water exchange per day during warm summer months to improve dissolved oxygen and temperature levels. To improve the migration of marine species into and out of impoundments, they suggested manipulating gates to allow more bottom-water flow.

Wilkinson thinks impoundment managers appreciated the scientific input.

“Every impoundment is different,” he says, “but we’re all trying to accomplish the same thing, to provide for wildlife.”

BRINGING TOGETHER REGIONAL OCEAN RESEARCHERS

Impoundments on the edge of land are easier to study than the extraordinarily complex ecosystems of the shoreline and the coastal ocean. In the early 1990s, researchers from many government agencies and academic institutions studying the physical, chemical, geological, and biological processes in near-shore waters of South Carolina and Georgia were struggling to leverage their resources to be more competitive in earning research grants.

To better focus regional research efforts, the Consortium and Georgia Sea Grant initiated the Coastal Ocean Boundary Interactions and Assessment (COBIA) program. The research goals were to identify, quantify, and model the exchanges of water, particulates, nutrients, contaminants, energy, and organisms across coastal boundaries. But individual research projects were less important than building a team approach among researchers and their



ALL FOR ONE. Ready for deployment off the coast of Charleston, the CAP2 buoy is one of an array of data-gathering devices that make up the Southeast Coastal Ocean Observing Regional Association, which the Consortium helped form to coordinate scientific work throughout the state and region.

PHOTO/UNCW COASTAL OCEAN RESEARCH AND MONITORING PROGRAM

institutions throughout the two states.

“We were developing collaborations across disciplines and across borders,” says Leslie Sautter, who led the COBIA program then and now is an associate professor in the Department of Geology and Environmental Geosciences at College of Charleston. “We laid the foundation to work together.”

The effort eventually expanded to

include North Carolina and Florida, and research took off. During the late 1990s and early 2000s, the Consortium’s coastal ocean researchers focused on continental shelf geology, coastal erosion, beach renourishment, and the connection between those three topics.

In another example of regional cooperation, the Consortium was approached in 2002 by a number of

university and ocean-observing leaders in the southeastern United States to lead the development of and initially manage the region’s ocean observations program. The Southeast Coastal Ocean Observing Regional Association (SECOORA) was launched the next year through a grant award from the NOAA Coastal Services Center to the Consortium. In 2010, SECOORA spun off as an independent, non-profit corporation. One of 11 ocean-observing regional associations established nationwide through the Integrated Ocean Observing System network, SECOORA coordinates coastal and ocean observing activities and facilitates dialogue among stakeholders in the southeastern United States.

SECOORA now serves a regional community of ocean scientists, coastal managers, and ocean-data users, including boat captains, harbor pilots, weather forecasters, and many others. In addition to gathering oceanographic and meteorological data, SECOORA invests in collection of biological information, such as acoustic data to better understand sound in the marine environment, and harmful algal bloom monitoring statistics to improve forecasting and management response. SECOORA also provides an administrative home for other regional issue-based networks, including the Southeast and Caribbean Disaster Resilience Partnership, the Southeast Ocean and Coastal Acidification Network, and FACT, an East Coast and Caribbean animal telemetry network.

“We are paying-it-forward in a way,” says Debra Hernandez, SECOORA’s executive director. “S.C. Sea Grant Consortium provided critical initial administrative support and leadership for SECOORA during our formative years. SECOORA is now providing that same service for other regional networks.”

Rick DeVoe, the Consortium’s executive director, was the association’s first board chair and returned to that position last year as SECOORA embarked on its second decade.

WATERSHED ECOSYSTEM STUDY INFORMS PLANNERS

During the 2000s, the Consortium coordinated a comprehensive effort to study the potential effects of development in coastal South Carolina. The South Atlantic Bight Land Use–Coastal Ecosystem Study (LU–CES), a five-year effort funded by the NOAA Coastal Ocean Program starting in 2001, focused on ecologic processes in salt marsh-tidal creek ecosystems in Beaufort County, specifically in the Okeechobee River watershed.

Researchers determined how much flow and volume the watershed yielded per square mile on a seasonal and annual basis. They created hydrodynamic models to help show how water moves through the watershed and how tides flush the marsh and river. They found multiple tides were necessary to flush particles released in the upper reaches of tidal creeks, which means runoff from developments along those stretches of the creeks could hang around through several days.

Salinity and dissolved oxygen varied among creeks, and seasonally within creeks. Thus the size and depth of creeks, and the type and elevation of adjacent land, makes a difference in the biological productivity of the creek. The major sources of contaminants found were road runoff and pesticides from suburban developments.

The project also predicted future land-use changes under a variety of growth strategies and estimated the resulting ecological impacts in Beaufort County and throughout the South Carolina coastal region.

“Development has multiple effects which force us to make choices,” the final LU–CES report states. “As with any modeling effort, the future urban area may not turn out exactly as predicted even with improved models, but the message has no error: If we do not act wisely today, we will lose what we have tomorrow.”



WATERY WORK. *With multiple major projects through dozens of years, the Consortium has delved into the ecological processes in salt marshes, tidal creeks, and coastal wetlands, putting researchers like Guy DiDonato and George Riekerk up to their knees in pluff mud to gather data.*

PHOTO/S.C. DEPARTMENT OF NATURAL RESOURCES

Beaufort County officials participated in the work, and local leaders took heed of the results. Environmental managers at Palmetto Bluff, a 20,000-acre development next to the May River, asked the research team to assist in developing a strategy for quantifying and reducing sediment and nutrient runoff into adjacent waterways as property was developed.

The LU–CES findings also factored into several guidelines in the natural resources chapter of Beaufort County’s comprehensive plan. The county required developers to leave vegetative buffers around waterways to capture sediment runoff, limited development on small coastal islands, enacted strict stormwater management regulations, and established a county-wide stormwater utility.

“Most of the steps that Beaufort

County has taken to preserve water quality can be traced back to the Beaufort Special Area Management Plan and LU–CES,” says Robert Merchant, assistant director of Beaufort County Community Development.

As the LU–CES work wrapped up, the natural progression was to synthesize decades of research that touched on the effects of land-use changes near tidal creeks, stormwater ponds, and impoundments. Thus was born a project dubbed Coastal Integrated–Demographic, Economic, Environmental Prediction (CI–DEEP).

The early projects “all had slightly different focuses,” says Denise Sanger, who served as the Consortium project manager for CI–DEEP and now manages the SCDNR Marine Resources Research Institute’s Environmental

Research section and the ACE Basin NERR. “All [studies] documented impacts, but some focused more on toxicology, some on water quality, some on the cycling of water through the system. Pulling them all together allowed us to tell a cohesive story.”

Because some of the work stretched back decades, researchers even could compare findings in locations where the land upstream of ponds or waterways had changed from forested to suburban habitat during that period. Development in specific cases led to downstream increases in environmental pathogens in the water and levels of trace metals and pesticides in sediments and animal tissue. But while development can be detrimental to ecological health, it also has been a driver of the economic health of the region. CI–DEEP aimed to incorporate science into conceptual models designed to show how development can best be accommodated in a sustainable fashion. Typical of such synthesis work, CI–DEEP answered some questions for state, county, and municipal planners while also raising many future research needs.

“Science may not always directly answer this specific question but it certainly provides the context for the public to make an informed choice in setting limits on, or, at the least, providing guidance on the nature of future growth and development,” according to the final CI–DEEP report. “Science can also play a role in identifying the likely outcomes of land-use decisions and resulting consequences of society’s decisions.”

The Consortium also took a lead in public stewardship of the waterways through its annual Beach Sweep/River Sweep litter cleanup. The inaugural event in 1988 was known simply as Beach Sweep. After Hurricane Hugo wiped out what would have been the second sweep in 1989, the event came back under the new name Beach Sweep/River Sweep in 1990 when SCDNR joined with the Consortium to lead inland waterway pickups.

It gradually grew into the

largest one-day litter cleanup event in the state. Eager volunteers throughout the state know to set aside the morning of the third Saturday of September to comb beaches, marshes, and waterways for bottles, cans, bags, and assorted debris. From 1988 through 2019, more than 154,000 volunteers removed more than 1,267 tons of litter from beaches and waterways.

The volunteers also collect data on the types and volume of litter, which can be useful in tracking the effects of local bans on smoking or use of plastic bags. Beach Sweep/River Sweep has grown into a citizen science project that improves the economic, environmental, and societal well-being of the state.

STORMWATER PONDS: THE INTERSECTION OF LAND USE, WATER QUALITY

As LU–CES and CI–DEEP research examined the movement of water through the coastal region, a relatively new factor in the equation kept growing in importance – stormwater ponds. Also known as wet detention ponds, they were not even a blip on the coastal radar in the Consortium’s early years. Almost all of the more than 9,000 development-related stormwater ponds in the state’s coastal counties have been built since 1980.

In fact, most of them have been built since 1991, when South Carolina legislators passed the Stormwater



COAST REPLUMBED. Stormwater ponds were hardly a blip on the coastal radar in the Consortium’s early years. Almost all of the more than 9,000 development-related stormwater ponds spread out through the region over the next 40 years.
PHOTO/JOEY HOLLEMAN/S.C. SEA GRANT CONSORTIUM

Management and Sediment Reduction Act, a response to the federal Water Quality Act of 1987. The new federal and state laws addressed sediments and toxins that wash, or run off, into waterways after heavy rains, or non-point source pollution. The goal is to reduce first-flush flooding during storms and prevent sediment, nutrients, and other pollutants washing off impervious surfaces (e.g., roads, roofs, parking lots) into coastal waterways. The regulations were especially important in coastal South Carolina, considering the increases in impervious surfaces required to support the rapid urban and suburban growth in the past three decades.

As stormwater ponds built in the first wave of construction after the 1991 law began to mature, their management became a growing issue. In many cases, the maintenance was



l radar in 1980, but regulatory changes that affected new development meant

turned over to homeowners' associations (HOAs) with little expertise on pond management and meager funds set aside for dredging or repairs of inflow or outlet pipes.

The Consortium, in collaboration with various stakeholders, identified ponds as a growing topic of concern and initiated the S.C. Stormwater Ponds Research and Management Collaborative in September 2014. Scientists and resource managers gathered to investigate and address the challenges associated with these systems. They aimed to better understand ponds' functionality, durability, benefits, and costs; to develop innovative engineering construction practices; and to share the latest information on pond design, maintenance, and management with the businesses, communities, and HOAs tasked with managing ponds.

The Consortium and partners in the ponds collaborative funded research projects that examined how algal growth in ponds affects dissolved oxygen in the water downstream, measured sedimentation rates to help pond owners plan for dredging operations, analyzed county and state pond construction and maintenance regulations, and determined how effective various pond designs are at pollutant removal. Erik Smith, manager of the North Inlet-Winyah Bay National Estuarine Research Reserve and assistant research professor at the University

of South Carolina Belle W. Baruch Institute for Marine and Coastal Sciences, guided several of those projects and contends they are tremendously important to the coast's future.

"The proliferation of ponds has amounted to a replumbing of the hydrology, changing the way water flows along the coast and what that means for good or for bad to our coastal receiving waters," Smith says. "The short answer is it's both good and bad."

Understanding how best to accentuate "good" aspects of stormwater ponds while discouraging "bad" aspects is the key. To further that goal, the results of research both inside and outside the state were incorporated into *Stormwater Ponds in Coastal South Carolina: 2019 State of Knowledge Full Report*. This encyclopedic overview published by the Consortium forms a

science-based foundation to address key pond management and policy questions and to guide efficient and cost-effective pond construction or retrofits in the future.

EXAMINING HOW BEST TO MITIGATE WIND DAMAGE, EROSION

Natural hazard mitigation has long been one of the Consortium's core missions. The 1980 research projects included studies of erosion of barrier islands and marshes. The Consortium also worked that year with Clemson University and the South Carolina Coastal Council, now Ocean and Coastal Resource Management under the S.C. Department of Health and Environmental Control (SCDHEC), on a major update of coastal building codes, the first since massive damage during Hurricane Gracie in 1959 made clear construction standards needed to be strengthened.

A little more than a decade later, those standards needed another update after Hurricane Hugo blasted South Carolina in 1989, causing \$5 billion in damages. Widespread structural damage from high winds prompted Consortium work with Clemson University civil engineering researcher Peter Sparks to determine how to improve wind resilience of new and existing buildings. Sparks found that 80% of the insured property damage by Hugo was caused by relatively minor wind damage to roofs, windows, and doors. That study led to more research on attaching roofs to walls more effectively, manufacturing nails that are more difficult for wind to pull out, and creating debris-resistant storm shutters and doors.

The researchers knew how buildings failed in hurricane-force winds and had some solutions. The next step was getting that information to government leaders who set building codes and manufacturers of building products, says Bob Bacon, the Consortium's former extension pro-



BUILDING LAB. After Hurricane Hugo devastated the coast in 1989, Consortium research focused on how to mitigate structural damage from winds and flooding, and the unoccupied house at 113 Calhoun Street in Charleston served as a demonstration site for various forms of structural reinforcement.

PHOTOS/S.C. SEA GRANT CONSORTIUM



gram leader during that period.

That's where the 113 Calhoun Street project came in. The City of Charleston owned a dilapidated, 125-year-old, three-story building at that location, and the Consortium and Clemson's extension program suggested it would be an ideal demonstration site for wind- and earthquake-resilient construction techniques. The city agreed, turning the building over to a foundation set up specifically for the project by the Consortium in 1997. A grant from the Federal Emergency Management Agency got the effort started, and smaller grants were awarded in drips and drabs. "In a way, that was good," Bacon recalls. "That allowed us to adapt as new products, new techniques, and new research came along."

Contractors replaced the unreinforced masonry foundation

supports with concrete footings and steel ties; moved heating and air-conditioning ducts from under the house to the ceiling and the air handlers outside the building to the second floor; raised first-floor electrical outlets; connected the roof and walls with hurricane clips; and designed interior walls and ceilings to minimize weak links in the structure. The project leaders also sought to raise the foundation by several feet to reduce potential flooding, but they were limited to a one-foot increase because of strict regulations on altering the appearance of historic structures. (Fast forward two decades, and those regulations have been tweaked to allow some homeowners to significantly raise historic structures which have experienced flooding over the last five years.)

The house at 113 Calhoun was turned into a demonstration laboratory

for hazard-resistant building materials, such as storm shutters and reinforced doors and windows. Wall coverings were left transparent on some portions to showcase the structural work. The goal was to increase public awareness of the availability and need for those resilient building methods and materials.

The building served as a lab and demonstration facility for more than a decade. The 113 Calhoun Street Foundation deeded the property to the non-profit Sustainability Institute in 2009, and it was later turned back over to city government and is now used for office space.

State and local building codes have been strengthened in the past two decades. Builders increasingly factor in wind-resistant materials and techniques in new or renovated structures, earning discounts from insurance companies. "All of those were things we dreamed would come into effect when we started these projects," Bacon says.

FOCUSING ON COASTAL PROCESSES AFFECTING BEACHES, BARRIER ISLANDS

A Consortium-funded study of barrier island erosion in 1980 was the first of many looks at these extremely important geological features. Beaches draw people to the coast, and keeping beaches healthy is critical to the coastal economy. But keeping beaches healthy is much easier when the natural dunes have room to move inland. As more and larger homes were built teetering on the edge of the state's beaches, the natural process needed a boost. Pumping sand from elsewhere onto beaches was the preferred method for renourishing beaches.

To identify resources to support beach replenishment, the Consortium funded studies to map tidal shoals suitable for mining renourishment sand in the 1980s and later generated a sand budget for a portion of the South Carolina coastal region as part of a multi-investigator study initiated

in 1994. Other projects aimed at understanding the processes that control erosion examined efficacy of different bulkhead designs, the historical movement of shorelines and tidal inlets, and long-term measurements of tides and waves.

From 1999-2006, the Consortium partnered with the U.S. Geological Survey on a multidisciplinary study of sediment movement along the state's northeastern coast, with a goal of improving projections of shoreline change. With no major inlets, the long stretch of coast from Murrells Inlet to North Myrtle Beach, known as the Grand Strand, features different geological forces than the central and southern coasts of the state. The S.C. Coastal Erosion Study mapped sand deposits on the inner coastal shelf, devised a sediment budget for renourishment planning, and created beach profiles to show the rates of beach erosion at a number of locations along the Grand Strand.

The Coastal Erosion Study "was a significant project in that it was a basis for so many things that came after it," says Paul Gayes, executive director of the Burroughs and Chapin Center for Marine and Wetland Studies at Coastal Carolina University and one of the study's researchers. The work was the first to look at the movement of sand throughout the Grand Strand as one system, and at the dynamics that help drive that system.

Employing regional scale framework and seafloor mapping approaches in concert with the U.S. Geological Survey, the study identified the role of the shallow geological framework influencing the Grand Strand as well as new sand borrow sites and proved to be a starting point for discussions about beach renourishment in the region. The study also took a broader approach to surveying the active beach, a change that has become common practice in subsequent years. Gayes notes that rather than measuring the upper beach out to five feet below water level, researchers looked farther offshore



BEACH BUILDING. *Understanding the process of barrier island erosion, shown here on Hunting Island, and finding the best source of sediment for beach renourishment has been an ongoing project for the Consortium since its beginning.*

PHOTO/WADE SPEES

because significant amounts of sand can settle farther out and still come back to a beach. The geologic framework maps have also aided subsequent studies of dredge disposal, renourishment sand resources, and even potential wind energy infrastructure placement in the future.

FLOOD MITIGATION MOVES TO TOP OF CONCERNS

Much of the LU-CES research mentioned earlier looked at water moving from land into coastal waterways. Not long after the LU-CES project wrapped up, the dilemma of water moving from waterways onto land became an increasingly pressing issue.

For decades, scientists had documented a slow, but barely

perceptible, rise in ocean levels. The average annual number of days in which the Charleston Harbor tide gauge topped 7 feet had risen from 2.1 in the 1950s to 4.3 in the 1970s. However, the rate of change accelerated; the number of days above 7 feet doubled again in the 1980s to 8.8, and nearly doubled again in the 1990s to 17.2. After a brief lull in the 2000s, the average went up to 36.4 flooding days per year in the 2010s.

Tidal flooding became a front-burner issue in the past four years, and Charleston Mayor John Tecklenburg in 2018 declared flooding the city's top issue. Charleston experienced 44 days with tidal flooding in 2015, 45 in 2016, 41 in 2017, 37 in 2018, and 76 in 2019. Also, one of the two daily high tides usually is much lower than the other, but 13 times in 2019 both tides topped

flood levels in Charleston, for 89 total flood events, according to NOAA.

The Consortium was ahead of the curve, sponsoring a workshop on sea-level rise in Charleston in 1984. John S. Hoffman, director of strategic studies for the U.S. Environmental Protection Agency (EPA), was among the speakers. His agency had recently come up with a sea-level rise projection with a mid-range estimate of 18 inches over the next 40 years.

"The information, however, does not tell us what we want to know most," Hoffman said. "Will sea level continue to rise? Will the rise be important? What should we do differently?"

Few in the audience shared Hoffman's desire to raise a concern.

"The meeting was attended by more than 100 people, many of whom had little prior awareness of global warming and sea-level rise," Davidson later wrote. "Shortly before the meeting, there was considerable pressure by local development interests

upon the local sponsors to cancel the meeting. Their concerns were based on apprehensions that highlighting the EPA case study would have a profound negative impact on residential and commercial development in the area. ... The general consensus of most local officials at that meeting was that the possibility and range of impacts from sea-level rise was too vague and too remote to affect any near-term planning."

But by 1988, a Blue Ribbon Committee on Beachfront Management established by the then-South Carolina Coastal Council recognized sea-level rise as a significant factor in beach erosion and questioned whether steps taken "in response to sea-level rise will be sufficient to protect the economically developed coast and its residents' way of life."

As it turned out, the 1984 EPA estimate was much too high. Sea levels rose about 6.5 inches from 1980 through 2019, but the rate of rise has accelerated in recent years. For

example, Charleston residents dealt with a record 76 tidal flooding days in 2019.

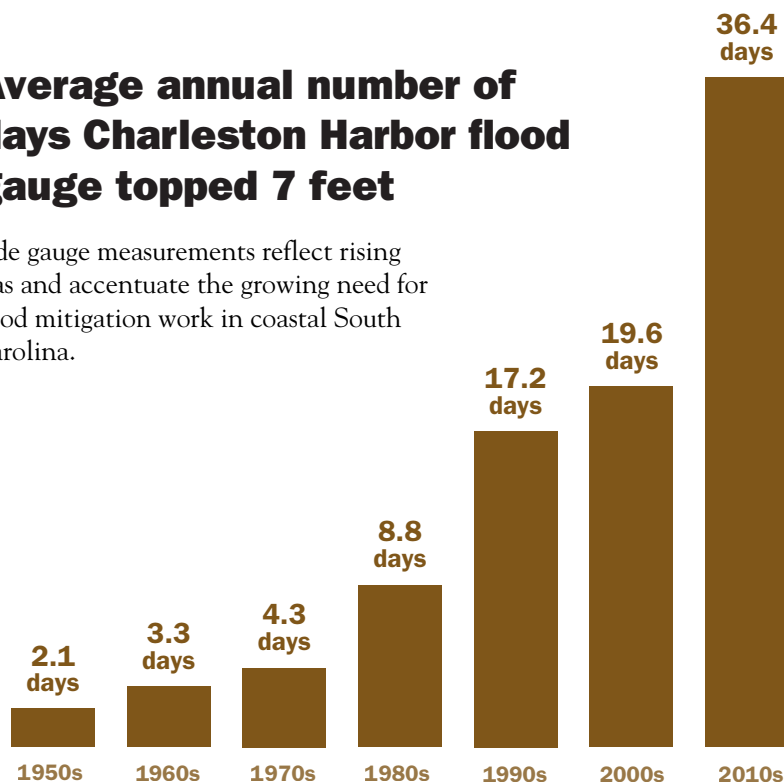
Since 2015, the Consortium has significantly expanded and focused its programmatic efforts on the issues related to flooding and resilience, as the recent acceleration of tidal flooding due to hurricane surge, more intense rain storms, sunny day flooding, and riverine runoff has presented major challenges to coastal communities. The Consortium worked with SCDHEC, the City of Charleston, and other partners to form the Charleston Resilience Network (CRN), which fosters conversations and cooperation among a variety of public and private entities affected by flooding. CRN has organized local coffee hours for resilience professionals, a presentation on the Dutch Dialogues process incorporated in similarly flood-prone New Orleans, and a knowledge exchange that brought together scientists and public officials from Charleston and the Norfolk, Virginia, region.

The Consortium, on behalf of the CRN and in collaboration with university, community, and government partners, secured significant funding through a NOAA Office for Coastal Management Regional Coastal Resilience Grant. Researchers at the College of Charleston and The Citadel have been developing models and maps and detailing the vulnerability of Charleston-area communities, identifying flooding "hot-spots," and documenting the capacity of neighborhoods and critical public infrastructure on a parcel-level scale to accommodate flooding events.

With this information, Consortium outreach efforts have involved work with municipal officials in Mount Pleasant and North Charleston on educational flood expos, and engagements with Folly Beach, Kiawah Island, the City of Beaufort, and Beaufort County on efforts to incorporate sea-level rise adaptation into their local comprehensive and hazard miti-

Average annual number of days Charleston Harbor flood gauge topped 7 feet

Tide gauge measurements reflect rising seas and accentuate the growing need for flood mitigation work in coastal South Carolina.



SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

GRAPH/CRYSTAL NARAYANA/S.C. SEA GRANT CONSORTIUM



RIISING CONCERN. *Flooding – whether from heavy bursts of rain, tidal flooding, or both – has become more common in the past 40 years, prompting the Consortium to focus on mitigation and planning to enable residents to learn to live with water.*

PHOTO/GRACE BEAHM ALFORD

gation planning documents.

With funding provided by the Department of Homeland Security's National Infrastructure Protection Plan, the Consortium collected and analyzed more than 50 existing tools, which have been designed to foster community resilience, to identify their purpose, design, and possible application for use in the Charleston region (and beyond), to boost resilience of small businesses, local governments, and neighborhoods to climate and weather events.

This information provided the

foundation for an effort to develop a tool which would draw pertinent information from the existing suite of available products, along with a means for users to access resource data for their own applications. So, in conjunction with the College of Charleston and Charleston-based software company BoomTown, the Consortium staged a hackathon that challenged software developers to create a local flood resilience web resource. The resulting web application, Chucktown Floods, provides a centralized portal for flood resilience tools and resources.

The concerns sounded at that sea-level rise workshop in 1984 have been recognized.

BACKING EXPANSION OF K-12 MARINE EDUCATION

At the Consortium's birth, it established study groups to examine the best ways to provide state residents "the opportunities to become knowledgeable and develop a sense of responsibility for the wise use of South Carolina's marine resources," according to the agency's 1979-81 report. Those groups recommended the Consortium develop a plan for coordination of marine-science education programs in K-12 schools, support research experiences for undergraduate and graduate students, and create opportunities for experts in marine research and education to reach out to the general public.

The S.C. Department of Education put an emphasis on environmental sciences early in the 1970s, joining a national trend that began in the 1960s. But marine science was just one relatively small component of the early K-12 environmental science movement. A K-12 education study committee formed by the Consortium in 1980 proposed to address the need for improved marine-science education by identifying available teaching resources, developing new materials, and training teachers to use them.

One of the first marine-education projects supported by the Consortium involved training K-12 educators from across the state at USC's Belle W. Baruch Institute for Marine and Coastal Sciences facilities on Hobcaw Barony near Georgetown. Between 1982-84, Wendy Allen, then director of continuing education with the Baruch Institute, and Alice Linder, S.C. Department of Education's environmental educator, led several marine-education courses and workshops that focused on the state's coastal ecosystems and engaged teachers in hands-on field and class-



NATURE EXPLORERS. Much of the Consortium's curriculum through the years focused on hands-on activities, as educators Dori-Lynn Coburn (left) and Beth Burkett of the Charleston County Park and Recreation Commission demonstrated at Beachwalker Park on Kiawah Island in 2015.

PHOTO/GRACE BEAHM ALFORD

room activities. Teachers explored salt marsh, beach, and freshwater communities, and learned how to set up a classroom aquarium, conduct a salt marsh transect, and combine the art of *Gyotaku* (fish printing) with a lesson on fish anatomy.

The teachers found national curricula and materials from other states often failed to match with local habitats. Those sessions led to the creation of *Sea Sampler*, a compilation of teacher-tested aquatic activities for the classroom and field, edited by Allen and Patty McLaughlin at USC's Baruch Institute and published by the Consortium. The *Sea Sampler* publications, one for elementary and one for secondary students, featured activities suitable for various grade levels, using an interdisciplinary approach that incorporated art, math, reading, science, social studies, or writing. Allen found that the process of creating curricula with the teachers was as important, if not more important, than the curricula itself.

"Curriculum materials or instructional materials by themselves don't get you anywhere," says Allen, who

recently retired from the Baruch Institute. "You really need that training component. If teachers are jazzed, they will use it. They need that experience doing the field activities."

The S.C. Marine Educators

Association (SCMEA) was formed in 1988 to build on the growing marine education momentum and encourage teachers to come together to share best practices. Allen says the organizers were uncertain if busy teachers would want to join another group. After all, many of them already were members of the Environmental Education Association of South Carolina. But the organizers of SCMEA's first gathering had to turn away teachers because the venue could handle only 100 people.

Like ripples spreading out from a stone dropped in a pond, marine-education efforts expanded. The Consortium and its partners published *Sea Things Objectively: A Marine Education Activities Booklet*, edited by Paula Keener-Chavis in 1991, and *Of Sand and Sea: Teachings from the Southeastern Shoreline* by Keener-Chavis and Leslie Sautter in 2002, the latter designed as a marine-science text for teachers who had no background in the subject matter.

Starting in 1994, the Consortium supported Coastal and Ocean Awareness for Southeast Teachers (COASTeam), a program developed by



FUTURE SCIENTISTS. The Consortium's *From Seeds to Shoreline*® program adds multiple levels to hands-on learning, as students cultivate smooth cordgrass at their schools and later plant the seedlings to help restore marshes.

PHOTO/GRACE BEAHM ALFORD

Sautter at the College of Charleston to train teachers in discovery-learning techniques. Elementary schools sent teams of two teachers for the training, and 11 teams were in the first class. As the program grew, middle school teachers joined in and new compilations of hands-on curricula were developed.

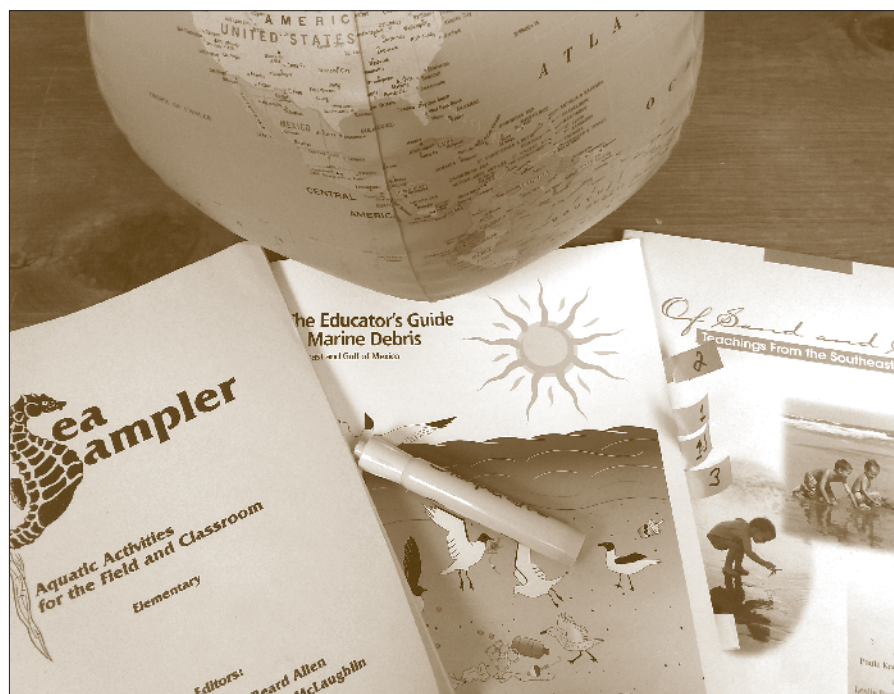
“That era was the beginning of the hands-on methodology for teaching science,” Sautter says. “We were showing how students can learn using active engagement instead of fill-in-the-blank worksheets.”

In 2000, the National Science Foundation (NSF) established a competitive grant initiative that resulted two years later in a national network of 12 regional Centers for Ocean Sciences Education Excellence (COSEE). The goal was for K-12 educators, ocean scientists, outreach specialists, and higher education faculty to collaborate to improve ocean-science literacy. The Consortium managed the COSEE–SouthEast (COSEE–SE) program, which covered South Carolina, North Carolina, and Georgia.

“We were trying to introduce teachers to the research concepts and methods, not necessarily writing curricula as much as giving them tools,” says Lundie Spence, who was hired by the Consortium to lead the effort.

During the first six years, COSEE–SE initiated summer programs connecting researchers and teachers with an emphasis to include under-represented populations. A working committee focused on barriers and incentives for diversifying the ocean-research workforce. The following five years shifted gears to provide workshops for researchers to do a better job of communicating with the public. With each change in emphasis, the earlier efforts were continued with limited budgets.

“It’s amazing how long it takes to build networks and how critical they are,” Spence says. “It gets richer and richer because you meet people. They



AQUATIC ACTIVITIES. *Through the years, the Consortium and its partners have put together a variety of curriculum guides designed to help educators bring marine science to life for their students.*

PHOTO/JOEY HOLLEMAN/S.C. SEA GRANT CONSORTIUM

have an outlet, and you have an outlet. Everyone says ‘Let’s see how we can work together.’ You end up with a really rich tapestry.”

There were plenty of COSEE–SE success stories. The South Carolina Amazing Coast program mentored teachers in grades 3-5 and helped classes gain experiential learning on field trips.

To support the growing Science, Technology, Engineering, and Mathematics (STEM) national initiatives, COSEE–SE joined with the Southeast Coastal Ocean Observing Regional Association to extend the Basic Observational Buoy program. This program, borrowed and adapted from educators in the Chesapeake Bay region, engaged middle- and high-school students in constructing small floating platforms armed with simple instruments to collect water data.

And partnering with the MIT Sea Grant SeaPerch program, COSEE–SE conducted workshops for teachers in three states. The effort encouraged students to build small, remotely operated vehicles (ROV), and then

compete in regional events using their ROV to maneuver and retrieve underwater objects. One Sea Perch teacher in Charleston used an ROV armed with a camera to observe the hull of the USS Yorktown at Patriots Point.

But the most impactful outcome of COSEE–SE might have been the networks it established, Spence says. In fact, the networks trace back to the *Sea Sampler* workshops, grew through COASTeam, and blossomed further under COSEE–SE. Aspects of those original programs were maintained as separate entities, and everyone involved collaborated.

COSEE–SE activities were supported over a 13-year period before NSF support ran out but its legacy continues today. Elizabeth Vernon Bell’s connection to the Consortium began with COSEE–SE, and in 2014 she became the first full-time educator on the Consortium’s staff. The networks are woven into the Consortium’s current major education efforts, including From Seeds to Shoreline®, the state’s first program for student-led salt marsh restoration.

Through the decades, the role of the Consortium's educational efforts remain the same: Find innovative ways and use partnerships to enhance STEM education, for teachers and students, through the study of coastal and ocean systems.

"The key is just getting kids excited about their local environment and getting them connected to what's around them, whether they live near the coast or in the mountains close to a stream or a river," Allen says.

FUTURE DEPENDS ON INVOLVING, TRAINING STUDENTS

From its start, the Consortium has worked to foster the next generation of coastal scientists, planners, and educators by involving graduate and undergraduate students in research projects and as interns working on its outreach programs. As the Consortium was ramping up in 1979, it provided support for a summer program that connected 12 undergraduate students to research projects in Charleston and Georgetown counties. The next year, a similar effort drew 10 students from Historically Black Colleges and Universities – South Carolina State University, Benedict College, and Voorhees College – for a summer marine-education program split between classrooms at USC in Columbia and field work in Beaufort County.

Since the Consortium started reporting its student numbers in 1988,

it has provided support to about 800 undergraduate and graduate students in research, internships, and national fellowships. Fifty-six nominees have been selected for Sea Grant's prestigious John A. Knauss Marine Policy Fellowship program and 20 for NOAA's Coastal Management Fellowship. Most have gone on to careers in marine education, research, or resource management or to related businesses or non-governmental agencies.

In 1997, the Consortium nominated Doug Marcy for a Coastal Management Fellowship. He studied post-hurricane recovery, developing an inventory of global information system data for beachfront structures within the state-imposed setback line in South Carolina. "This was my first 'job' out of grad school and was a great opportunity to learn the Coastal Zone Management Act and how a state like South Carolina implemented it and enforced it," Marcy says. "I made a lot of good contacts from other agencies, including NOAA and the U.S. Army Corps of Engineers (USACE)."

Marcy landed a job with USACE after the fellowship and later moved on to NOAA, where he now serves as a coastal hazards specialist with the Office for Coastal Management in Charleston.

In some cases, workforce development means providing promising young people a career boost. In 1993, Robert Boyles was looking for the right starting point after completing a

year in Washington, D.C. as a Knauss fellow. (He was nominated for the fellowship by the University of Delaware Sea Grant College Program.) He wanted to work in resource management at the state level, and his fiancé was living in South Carolina.

Margaret Davidson, Consortium executive director from 1983-1997, was impressed with Boyles and offered him a job with the Consortium. He spent three years with the Consortium, starting as an extension agent working on economic development and later serving as program manager.

Boyles left the Consortium for a job at SCDNR's Marine Resources Division in 1997 and, in early 2020, was selected as director of the agency, which earned the former employee a place on the Consortium's board of directors.

"Sea Grant unlocked all of that for me," Boyles says. "The program always is asking why a problem is important and trying to figure out how to make things better."

FOSTERING CULTURAL HERITAGE AWARENESS AMONG COASTAL RESIDENTS

From the beginning, cultural history was an important component of the Consortium's work. The first round of Consortium projects in 1980 included funds to compile histories of the state's sea islands, tabby structures, and hurricane impacts, and to back programs at the Penn Center, a hub of African-American cultural programs on St. Helena Island. In 1982, the Consortium established its Coastal Heritage Program and began publishing *Coastal Heritage*, then a four-page bulletin of brief items.

The stated goal of the Coastal Heritage Program was to examine "the interaction of the environment, the economy, and the culture historically" to provide insight for local and state decision-makers. The first issue of the program's bulletin featured heritage recipes for oyster soup and pickled

Students supported by S.C. Sea Grant Consortium, 1988-2019

808 College students supported by S.C. Sea Grant Consortium through research grants, internships, or jobs

56 Sea Grant John A. Knauss Marine Policy Fellowships

20 NOAA Coastal Management Fellowships

GRAPHIC/CRYSTAL NARAYANA/S.C. SEA GRANT CONSORTIUM

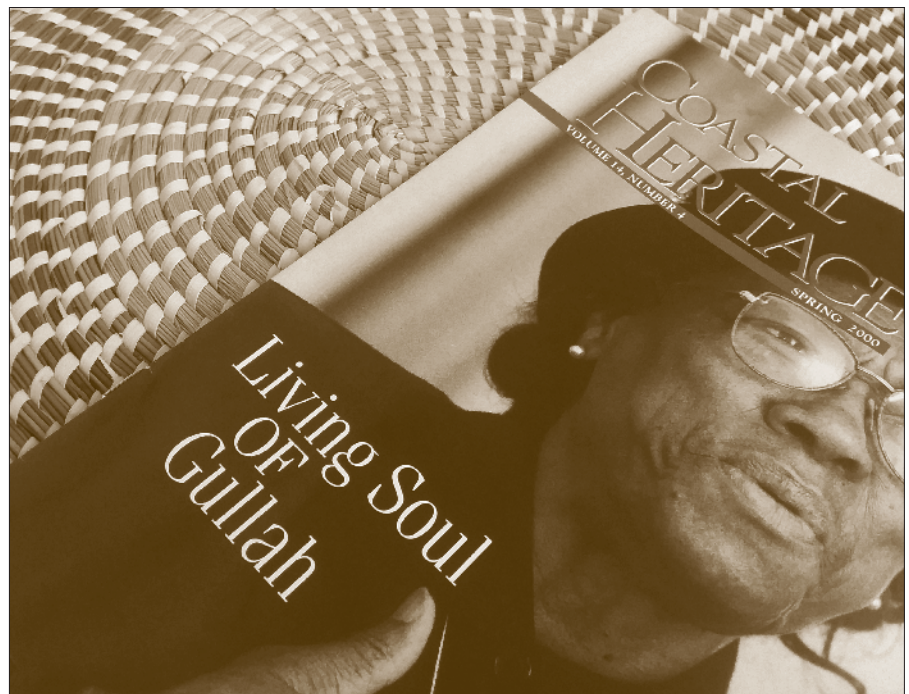
shrimp, an excerpt from *Narratives of Early Carolina* by A.S. Sally, and a note on efforts to maintain the historic Bluffton Oyster Co-op. Forty years later, workers still shuck oysters at the waterfront facility, which has survived economic ups and downs and ownership changes and now is known as Bluffton Oyster Company.

As for *Coastal Heritage*, it evolved into a 16-page magazine featuring one in-depth examination of an important coastal topic each quarter. The publication provides an outlet for sharing research results, detailing important trends, and tracking the effects of scientific and cultural changes. And its format provides a way to look to the past, understand how it affects the present, and how it can drive the future.

For instance, when rising seas and temperatures were just beginning to raise concerns worldwide, the Summer 2003 issue “Hothouse Planet,” started what ended up being a series on climate change. The Winter 2007 *Coastal Heritage* weighed in with “Rising Tide: Will Climate Change Drown Coastal Wetlands?” The narrative concluded with: “Rising sea level is unavoidable, scientists say. But states, localities, and property owners can begin adapting to change by creating or improving coastal marshlands.” Subsequent magazine issues dealt with the effects of climate change on coastal property insurance, general ocean health, and extreme weather events.

Some issues spotlighted Consortium research. The Winter 2001 issue detailed the dangers associated with invasive non-native species like fire ants, lionfish, water hyacinth, and zebra mussels. The Winter 2010 issue explored the potential for wind energy production off the S.C. coast. The Summer 2014 issue helped raise concern about microplastics in the ocean.

And the magazine frequently returns to its roots to celebrate unique aspects of South Carolina’s cultural heritage. Some of the most popular



PROVIDING PERSPECTIVE. Starting as a bulletin in 1982, *Coastal Heritage* has endeavored to both reflect and shine a light on the coastal cultures and ecosystems special to South Carolina.

PHOTO/JOEY HOLLEMAN/S.C. SEA GRANT CONSORTIUM

and powerful issues dealt with Gullah culture created by the descendants of formerly enslaved Africans living on the state’s sea islands. “Living Soul of Gullah,” the Spring 2000 issue of *Coastal Heritage*, presaged two decades of increased recognition of the culture.

For much of the 1900s, people with African roots who remained on the sea islands seldom referred to themselves as Gullah. The term was used as an insult in the press for African-American leaders during Reconstruction. “You can understand why for a long time people didn’t want to be identified as Gullah,” says Heather Hodges, executive director of the Gullah Geechee Cultural Heritage Corridor, a National Heritage Area designated by Congress in 2006.

The attitude about using Gullah as a cultural description began to change in the late 1980s, Hodges says, after historian Joseph Opala organized a series of homecomings connecting the Gullah people of S.C. sea islands with people in their ancestral homeland in Sierra Leone. The newfound

Gullah pride prompted a group of leaders to begin celebrating that heritage during events at Penn Center, at community festivals, and through the designation of the Gullah Geechee Cultural Heritage Corridor. (Generally, the community is referred to as Gullah in South Carolina and North Carolina and Geechee in Georgia and Florida.)

Coastal Heritage chronicled aspects of Gullah culture, as well as the rise in interest in that history, in the Winter 2004-2005, Summer 2006, Winter 2008, Fall 2012, and Winter 2014 issues. Community leaders, historians, artisans, and chefs drove the trend to explore more deeply what once was hidden. “There are more people incorporating Gullah Geechee in important cultural work,” Hodges says. “Young people hear that their culture is dying, their language is dying, but that’s not what they’re seeing all around them.”

More broadly, *Coastal Heritage* has delved into the customs, history, social institutions, and ecosystems that together form the foundation of the modern culture of coastal South

Carolina. Through the years, the Consortium's flagship publication has grown into one of its major education and outreach efforts.

BUILDING A FUTURE ON THE FOUNDATION OF FOUR DECADES OF COASTAL SCIENCE

In 2020, the Consortium is exploring new ways to examine the coastal culture and environment, new ways to track factors shaping the present, and new ways to use science to plan for the future.

In terms of education, the 2020 round of research projects includes one that will use musical theater and puppetry to bring the ocean environment to life, especially for students at inland schools. The 2020 aquaculture focus examines new spawning techniques for farmed oysters. In fisheries, the emphasis is on how stock enhancement with hatchery-reared fish can help sustain the wild population of cobia and spotted sea trout. Those subjects could have just as easily been on the Consortium's 1980 research agenda.

If someone took a trip in a time machine from 1980 to 2020, however, they would have been perplexed by questions posed by some of the Consortium's other new projects, such as:

- Can craft brewery byproducts be easily repurposed as fish food?
- What are the special vulnerabilities of socio-economic groups to sea-level rise?
- What portion of microplastics from tire wear enter the estuarine system through stormwater runoff?
- What is the best way to set up a smartphone app to get accurate tidal flooding information to residents in real time to help them plan their daily lives?

Craft breweries, microplastics, and smartphone apps were not in the coastal South Carolina vernacular in 1980. And only a few forward-thinking scientists and planners were concerned about the specter of sea-level rise or



MOVING FORWARD. *As the Consortium moves into its fifth decade, researchers build on work from the past to guide future study, such as College of Charleston graduate student Sarah Kell exploring the link between black microplastic particles in the Charleston Harbor and stormwater ponds.*

PHOTO/GRACE BEAHM ALFORD

the prospect of high tides inundating coastal roads several times a month. Questions have changed over the past four decades, and so have the potential answers.

Changes in species distribution prompted by climate change might lead to the birth of new forms of aquaculture (Malaysian prawns, anyone?). Innovative architecture combined with smart building codes could reduce the damage from severe storms. Adapting to flooding could present new possibilities for recreational opportunities in parks built to briefly hold the pulse of water after heavy rain.

"I like to think that there are plenty of young scientists out there who would love to jump on these topics," Sandifer says. "They can mix the sorts of things we've done traditionally in fisheries and fisheries management, in aquaculture, in coastal zone management, and then look at how they could contribute

to a whole new way to look at the problems we have."

The technology of 2020 can entice youngsters to stay inside, but it also can draw them to explore in person what they see on a computer or smartphone screen. The explosion of citizen science provides opportunities for young people to identify creatures that show up on wildlife cameras or to plant marsh grass that stabilizes creek banks. Wendy Allen would like for citizen science programs aimed at K-12 education to go through a process like *Sea Sampler* did in South Carolina, exploring what is most appropriate for the region and works best for local educators.

The new wave of researchers and educators are fortunate in that they won't have to start from scratch in the coming decades. They can ground their efforts on a foundation of coastal science work established during the past 40 years by the Consortium and its partners. ♡



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S.C. State's Clark elected Consortium board chair

South Carolina State University (SCSU) President James E. Clark has been elected chair of S.C. Sea Grant Consortium's Board of Directors,

and began his term on January 1, 2020.

Clark replaces University of South Carolina President Emeritus Harris Pastides, who served three terms as board chair. The Consortium's board consists of the chief executive officers of its eight member institutions: Clemson University, Coastal Carolina University, College of Charleston, Medical University of South Carolina, SCSU, S.C. Department of Natural Resources, The Citadel, and University of South Carolina.

Clark, who became SCSU president in July 2016, earned a bachelor's degree in electrical engineering and computer science and a master's degree in management/marketing, both from Massachusetts Institute of Technology. He has worked for business giants General Electric, Gillette, Exxon International, and AT&T. His experience at Fortune 500 companies shaped his belief that a data-driven, results-oriented business approach launches and drives positive outcomes.

"I am looking forward to serving as the chairman of the Sea Grant Consortium board to support the



JAMES E. CLARK
PHOTO/SOUTH CAROLINA
STATE UNIVERSITY

conservation of South Carolina's coastal resources and our efforts to create a sustainable economy and environment," Clark said. "I offer my full support to Executive Director Rick DeVoe as I continue the great work that Dr. Harris Pastides provided as the former chairman." 🐟

Consortium awards funding for eight research and outreach projects

The S.C. Sea Grant Consortium has selected eight peer-reviewed research and outreach projects to be funded during the 2020-2022 cycle, covering topics which include stocking and enhancement of fishery species, using brewery by-product as feed in fish aquaculture, examining the impacts of climate change, tracking the microplastics in stormwater runoff, and supporting a new education effort with a musical theater component.

These projects are among the research, extension, communications, and education efforts supported by funds from the NOAA National Sea Grant College Program. The following are summaries of the 2020-2022 research and outreach proposals.

HEALTHY COASTAL ECOSYSTEMS

Urban stormwater runoff as a source of microplastic and tire wear particles in coastal waterways: Transport, cumulative impacts to biota, and mitigation.

Peter van den Hurk, Clemson University, John E. Weinstein, The Citadel, and Barbara Beckingham, College of Charleston

Previous work by Consortium researchers showed black microplastic particles are common in Charleston Harbor, the majority of the particles result from tire wear on highways, and black microplastic particles can have adverse effects on some estuarine organisms. This project takes that line of research forward to determine the role of stormwater runoff as a pathway for microplastics in coastal waterways.

Researchers will examine microplastics and tire debris in storm-sewer catch basins, measure the contribution of stormwater ponds in the movement of microplastics and how that contribution could be minimized, and further study the long-term responses of estuarine organisms to microplastic exposure. The researchers believe understanding how microplastics reach coastal waters is critical to informing policy and management decisions.

SUSTAINABLE COASTAL DEVELOPMENT AND ECONOMY

Climate risks, infrastructure systems, and income disparity: Impacts of sea-level rise on social inequality in South Carolina's coastal communities. Mostafa Batouli, The Citadel, and Ismail Farajpour, S.C. State University

For generations, low-lying land was the least desirable, and thus communities of the economically vulnerable tended to form in those areas. As sea levels rise, adaptation creates unique challenges in those communities. Researchers aim to investigate the interaction of sea-level rise stressors, physical conditions of civil infrastructure, and the vulnerability of socio-economically disadvantaged populations in South

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Carolina. The goal is to identify adaptations which can improve resilience for low-income families.

Researchers will combine interactive sea-level rise projections with mapping of socio-economically vulnerable populations, and then suggest how design, operation, and management of physical infrastructure networks can impact resilience, with a focus on low-income communities. The information will be shared with public agencies that make infrastructure decisions, including S.C. Department of Transportation, S.C. Department of Health and Environmental Control, and S.C. Rural Infrastructure Authority.

WEATHER AND CLIMATE RESILIENCE

Charleston regional flood warning M-App. Norman S. Levine and Emma Paz, College of Charleston

Chronic flooding has become a component of life in coastal South Carolina. Business and community leaders, as well as residents, need real-time information on flooding throughout the region not only to schedule their day-to-day lives but also to plan for the future.

Researchers will develop a database of modeled tidal flooding severity for every road in Charleston County, as well as a countywide rainfall flood mapping product based on one-inch intervals. Estimated flood impacts of tidal and precipitation data then will be combined in a real-time application, called M-App, to communicate the short-term vulnerability in a specific location. M-App will be designed to pair with Chucktown Floods, a data and mapping portal

built to consolidate information on flood resources.

SUSTAINABLE FISHERIES AND AQUACULTURE

Developing a sex-linked DNA marker for cobia (Rachycentron canadum) using next generation sequencing technology for use in stock enhancement, aquaculture efforts, and stock assessments. Tanya L. Darden, Michael R. Denson, and Matt J. Walker, S.C. Department of Natural Resources

Cobia is a popular recreational fishery, and the species gathers in large numbers in high-salinity estuaries on the Atlantic coast and the Gulf of Mexico to spawn, including Port Royal Sound in South Carolina. Heavy fishing pressure in inshore waters has reduced the population in the past two decades, prompting harvest restrictions

and seasonal closures of the fishery. S.C. Department of Natural Resources grows hatchery broodstock for a cobia stock enhancement program.

This project aims to improve the success of stock enhancement by determining the sex ratio of wild populations through a non-lethal and minimally invasive identification tool. The research goal is to use next generation sequencing to develop a sex-linked DNA marker for cobia and use that information to assess the genetic health and hatchery contribution to cobia in South Carolina.

Modeling optimal responsible stocking strategies for spotted seatrout. Tanya L. Darden and Michael R. Denson, S.C. Department of Natural Resources

Spotted seatrout (*Cynoscion nebulosus*) populations are vulnerable to catastrophic winter kills at least once



Tidal creeks are linked to the Consortium's latest research projects which touch on microplastic pollution, flooding, and fish stocking.

PHOTO/SHUTTERSTOCK

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a decade. Enhancing the wild spotted seatrout population with hatchery-raised stocks after those catastrophic kills requires a balance to ensure the ideal genetic diversity and population size for long-term species adaptability.

Hatchery managers have few established protocols for determining appropriate stocking numbers or evaluating the potential risks of stocking on the genetic health of the wild population. Researchers will compare stocking strategies at multiple population abundance levels to determine the best practices for spotted seatrout conservation efforts.

Evaluating shellfish pond potential to produce a compatible crop of marine fish, tripлетail (Lobotes surinamensis). Jason Broach and Michael R. Denson, S.C. Department of Natural Resources

Tripletail, a fast-growing fish species found in tropical and subtropical oceans, is popular for its firm meat and mild flavor. Restaurants in the southeastern United States have reported a large demand for tripletail that isn't being met by U.S. commercial fisheries, which sets up the potential for a strong aquaculture product.

The few attempts at tripletail aquaculture in the southeastern United States so far have been unsuccessful. Researchers plan to try new methods in recirculating aquaculture systems using fish food with hormones designed to induce spawning. They also will examine the effectiveness of synthetic, waterborne hormonal pheromones to improve spawning.

Utilizing local Charleston, South Carolina craft brewery by-products to fill nutritional gaps in sustainable fish feeds for juvenile red drum, Sciaenops

ocellatus. Aaron M. Watson, Fabio Casu, and Michael R. Denson, S.C. Department of Natural Resources

This project will evaluate the feasibility of utilizing dried spent brewer's grains, a by-product of the brewing process, for use in feeds for fish aquaculture. Most craft breweries in coastal South Carolina now donate their by-product to farmers for cattle or pork feed, but the growth in the number of breweries means there's more by-product than those farmers can use. A new use for the by-product would keep it out of landfills and offer local aquaculture operations a locally sourced, cost-effective alternative to fishmeal.

Researchers will determine if spent grains contain sufficient nutritional content to be utilized as an ingredient in fish feed formulations, is digestible for juvenile red drum, and can be incorporated into feed without negative consequences to fish growth or health. Three local breweries, Tradesman Brewing Co., LowTide Brewing, and Holy City Brewing, have agreed to assist and collaborate on this project.

SCIENTIFIC LITERACY AND WORKFORCE DEVELOPMENT

Something Very Fishy: A Marine Science STEAM program for elementary schools. Michael Childress, Clemson University, and Meghnaa Tallapragada, Temple University

Clemson University researchers will team with Educational Entertainment LLC to present a musical theater and science outreach program called "Something Very Fishy" to K-5 students in the Upstate, some of whom have never experienced

an ocean up close. This musical puppet show will be paired with hands-on science exhibits to present the struggles of marine life in a changing ocean and options for helping protect that ecosystem.

After the show, students embark on an imaginary field trip to the Florida Keys National Marine Sanctuary, with Clemson students portraying different careers in the STEAM (Science, Technology, Engineering, Arts, and Math) disciplines at each stop of the trip. The project will train Clemson undergraduate and graduate students to lead marine-science outreach programs and instruct K-5 teachers on how to take the lessons of this unique science exhibit back to their classrooms. ♡

Carr, Gaines join Consortium staff

The S.C. Sea Grant Consortium has two new staff members – Information Technology Resources Manager Chris Carr and Living Marine Resources Program Specialist Graham Gaines.

Carr has a bachelor's degree in business from University of South Carolina and 20 years of IT management experience, including stints with College of Charleston and Medical University of South Carolina. In his



CHRIS CARR



GRAHAM GAINES

PHOTOS/GRACE BEAHM ALFORD

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new role, Carr will be responsible for the agency's hardware and software and ensure that infrastructure is in compliance with security policies.

Gaines has a bachelor's degree in English studies from University of Georgia and a master's of natural

resource management from University of Akureyri in Iceland. During his career, he has helped develop community-based fisheries and aquaculture improvement projects with the Peace Corps in the South Pacific and facilitated new fisheries conservation

strategies in Micronesia, Alaska, and Georgia with The Nature Conservancy. In his new role, Gaines will contribute to research motivated by living marine resources community needs and provide operational and technical support for stakeholders. ♡

Scholars program provides tribute to Margaret A. Davidson

By Rick DeVoe

Throughout the last 40 years, I have had the utmost pleasure and opportunity to work with and for the most remarkable people, but for many of us in the coastal and ocean world, one stood out among them all – Margaret A. Davidson.

Margaret, who passed away in 2017, directed the S.C. Sea Grant Consortium from 1983 to 1997 and went on to become one of the pre-eminent thought leaders at the National Oceanic and Atmospheric Administration (NOAA). There was no other person like her, and everyone who experienced Margaret's wisdom, tenacity, insightfulness, finesse, and political know-how became better for it. She was my mentor; I know I could not have survived, and at other times thrived, without her guidance and the confidence she placed in me.

Margaret was integral in the formation of the Consortium. She and I came to South Carolina in 1980 as recent graduates of the University of Rhode Island's geography and marine affairs program as staff to operationalize the agency, and she was selected as the agency's executive director in 1983. Margaret went on to work for NOAA and established the Coastal Services Center (CSC) on the old

Charleston Navy base. Then she served as acting director of NOAA's Office for Ocean and Coastal Resources Management (OCRM) and guided the merger of NOAA CSC and NOAA OCRM. Always looking for a new challenge, Margaret then became NOAA's senior leader for coastal inundation and resilience.

Margaret has been devotionally described in many ways – *Visionary, Champion, Mentor, Intellectual, Networker, Leader, Trailblazer, Unique, Compassionate, Extraordinary, Respected ... and Colleague and Friend* – by her peers, colleagues, and acquaintances. She was adamant about young people within the context of the diversity of face, place, and space, and with the perspectives and passion they bring to the table. She did so knowing that it is our young people who will have to step up and take on future challenges society must address, especially in the hope of becoming more resilient. And she



MARGARET A. DAVIDSON
PHOTO/NOAA-OCRM

always found that working outside the box ultimately results in more positive outcomes and effective change.

This issue of *Coastal Heritage* examining the Consortium's first 40 years is dedicated to Margaret, for her leadership set the stage for much of the work detailed here.

More substantially, in recognition of Margaret's career-long mission as an agent of change, the Consortium is establishing the **Margaret A. Davidson Undergraduate Resilience Research Scholars program (Davidson Resilience Scholars)** to provide opportunities for upcoming undergraduate students to contribute novel and innovative ideas and solutions to help address the challenges we face as we look to become a more resilient society. We are creating this program in her name with the hope of cultivating the next generation of professionals – resilience leaders, teachers, mentors – and to honor her life and legacy. ♡



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EBBS & FLOWS

S.C. Water Resources Conference

*Columbia, South Carolina
October 14-15, 2020*

This conference will provide a forum for discussion of water policies, research projects, and water management. The theme is "Management and Research of a Critical Resource for the Environment, Society, and Economy." The goal is to prepare for and meet the growing challenge of providing water resources to sustain and grow South Carolina's economy while preserving natural resources. For information, visit www.clemson.edu/public/sc_water_resources.

Stormwater Pond Management Conference

*N. Charleston, South Carolina
November 18, 2020*

This conference will provide a forum to present the latest research, resources, and tools on pond management for Lowcountry stormwater pond owners. Topics will include a plenary session, Q&A session, and presentations on pest management, aquatic weed management, wildlife habitat, and upland management. Contact Guinn Wallover at cggarre@clemson.edu or Beatriss Calhoun at beatris@clemson.edu for information.

A Community on Ecosystem Services Conference

*Bonita Springs, Florida
December 14-17, 2020*

This conference will bring together professionals, researchers, and policy-makers involved with ecosystem services to provide an open forum to share experiences, methods, and tools for assessing and incorporating ecosystem services into public and private decisions. The focus will be to advance the use of science and practice in resource management and other societal decisions. For information, visit conference.ifas.ufl.edu/aces.

Subscriptions are free upon request by contacting: Susan.Ferris.Hill@scseagrant.org

ATTENTION SCHOOL TEACHERS! The S.C. Sea Grant Consortium has designed supplemental classroom resources for this and past issues of *Coastal Heritage* magazine. *Coastal Heritage Curriculum Connection*, written for K-12 educators and their students, is aligned with the South Carolina state standards for the appropriate grade levels. Includes standards-based inquiry questions to lead students through explorations of the topic discussed. *Curriculum Connection* is available online at www.scseagrant.org/coastal-heritage-curriculum-connection.

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